DIMENSI: Journal of Architecture and Built Environment, Vol. 51, No. 2, December 2024 DOI: https://doi.org/10.9744/dimensi.51.2.107-112
ISSN 0126-219X (print) / ISSN 2338-7858 (online)

Utilization of Disposable Mask Waste and Coconut Fiber as an Acoustic Composite Material

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Article Info:
Submitted: January 30, 2024
Reviewed: October 20, 2024
Accepted: December 15, 2024

Keywords:
Acoustic material; coconut fiber; disposable mask.

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Abstract

This research aims to utilize disposable mask waste and coconut fiber as an acoustic composite material and identify its sound absorption characteristics. The method used in this research is an experiment to produce four samples with different non-woven polypropylene and coconut fiber composition. The samples went through multiple tests to identify its morphology, mass change in different temperatures, density, and sound absorption coefficient. The result of this research shows that these materials display sound absorption characteristics and can be applied for acoustic purposes. Acoustic material with 100% non-woven polypropylene displays the best sound absorber characteristics, especially for 500Hz frequency sound. However, acoustic material with composition of 90% non-woven polypropylene and 10% coconut fiber shows a better sound absorption coefficient in 2000Hz frequency.

INTRODUCTION

Disposable mask waste has been rapidly increasing since the Covid-19 pandemic. It was estimated that as many as 122.538.579 masks were thrown away per day in Indonesia (Benson et al., 2021). Even though we're already entering the post-pandemic period, mask waste has not yet decreased because it has become part of our daily lifestyle (Dey et al., 2023). Another reason is because disposable mask is made from non-woven fabric of polypropylene plastic which does not easily decompose in nature and therefore has the potential to damage the environment (Chua et al., 2020). Meanwhile, efforts to process mask waste using incinerator and autoclave have a potential to produce dangerous emissions (Prasetiawan, 2020; Soemiarno, 2020). There is another alternative for processing disposable mask waste which is through a recycling process because polypropylene has a fairly high melting point (Badan Riset dan Inovasi Nasional, 2021). However, mask waste is included as B3 waste (Hazardous and Toxic Materials), so it can bring bad effects on humans if it is not disinfected before using (Priyatama et al., 2021). Previous researches agreed that heating at temperature of 70°C-75°C for 30 minutes is the most suitable method for mask disinfection (Celina et al., 2020; International Medical Center-Beijing, 2020).

Disposable mask waste has the potential to be used as an acoustic material because of the porous and fibrous nature of the material. This nature is considered to be able to absorb sound energy (Milawarni & Saifuddin, 2018). Pores or voids have an important part in acoustic material because it acts as the medium for sound wave dissipation (Amares et al., 2017). Previous research that developed acoustic material from mask waste shows that this material is the most effective at absorbing sound with ≥1000Hz frequency (Privera et al., 2023). Meanwhile, similar research suggests that disposable mask waste is better at absorbing sound with 400-500Hz frequency (Febriyanti et al., 2024).

Therefore, in order to maximize sound absorption ability in various frequency range, another material is added to make a composite material. Previous research on making composite acoustic materials from coconut fiber shows that this material has the ability to absorb sound at various frequencies, especially ≤ 1000Hz (Maghfiroh, 2023; Said et al., 2020). Indonesia is one of the largest coconut producers in the world with plantation coconut production reaching 2.8 million tons per year (Badan Pusat Statistik, 2021). As much as 35% of the total production creates waste in the form of coconut fiber which is the outer part of coconut (Ningtyas et al., 2022). Currently, the use of coconut fiber is mostly limited to fuel, handcrafts, or planting media (Kusumawati et al., 2023).

From this explanation, composite material of disposable mask and coconut fiber has the potential to be an acoustic material that can absorb various frequency sounds more optimally. Apart from that, this step is also an effort to reduce the accumulation of waste, especially mask waste which is still rarely used. Therefore, this research develops an acoustic material based on non-woven polypropylene composite from disposable mask and coconut fiber waste. This research also identified its sound absorption characteristics. It is hoped that this innovation can solve the problem of disposable mask and coconut fiber waste and can be used as an alternative to acoustic material.

METHODS

The type of method used in this research is an experiment which is divided into several steps. The initial step was to prepare disposable mask and coconut fiber waste. Nose wire from the mask was removed as the experiment only used the non-woven polypropylene fiber. Then, it was sterilized with 70% alcohol and heated at 75°C for 30 minutes. Meanwhile, preparation of coconut fiber waste was conducted by delignification using a 5% NaOH solution. The next step was to cut the non-woven polypropylene fiber from disposable mask waste and coconut fiber until they were relatively the same size.

The following step was to make the acoustic material. There were four samples made with various waste material compositions which described in Table 1. Each composition was mixed with the same amount of PVAc glue and molded into panels with equal diameter and thickness. Then, the panels were dried out in an electrical oven at 100°C for 120 minutes.

Table 1. Samples Description

Sample	Composition	External Appearance	Diameter	Thickness
1	100% non-woven polypropylene			
2	95% non-woven polypropylene; 5% coconut fiber			
3	90% non-woven polypropylene; 10% coconut fiber		10 cm	3 cm
4	85% non-woven polypropylene; 15% coconut fiber			

After obtaining four samples, the next step was to identify the characteristics of acoustic materials through its morphology, mass change, density, and sound absorption coefficient. Scanning Electron Microscopy (SEM) test was used to analyse the morphology of the acoustic materials, especially the size of the pores on the material surface. Another testing was also carried out using Thermogravimetric Analysis (TGA) test to determine the mass change experienced by the materials in different temperatures. Material's density was measured through the ratio of mass to volume of the material. From this process, the density value of each acoustic material sample was acquired.

Sound absorption test was carried out by installing the sample one by one between two tubes with one tube had a sound source in the form of a Bluetooth speaker and the other tube had a sound level meter. The speaker was connected to a laptop that generated sound at frequencies of 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz, and 4000Hz. The sound would pass through the sample and the sound level would be measured by the sound level meter. The same test was repeated throughout 4 samples. The schematic view of this test can be seen in Figure 1.

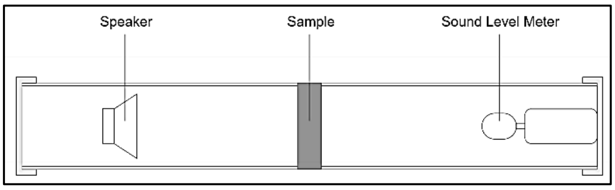

Fig. 1. Schematic View of the Sound Absorption Test

The initial test was also conducted without any sample in between the tube to determine sound level that acted as the incident energy (E_I). Meanwhile, absorbed energy (E_A) was the difference between sound level with sample and without the sample (E_I) in between the tube. From the sound level data, sound absorption coefficient (α) of each sample was calculated with equation 1.

$$\alpha = E_A/E_I \tag{1}$$

RESULTS AND DISCUSSION

Samples Morphology

The Scanning Electron Microscopy test result shows the morphology of the acoustic material samples which can be seen in Figure 2.

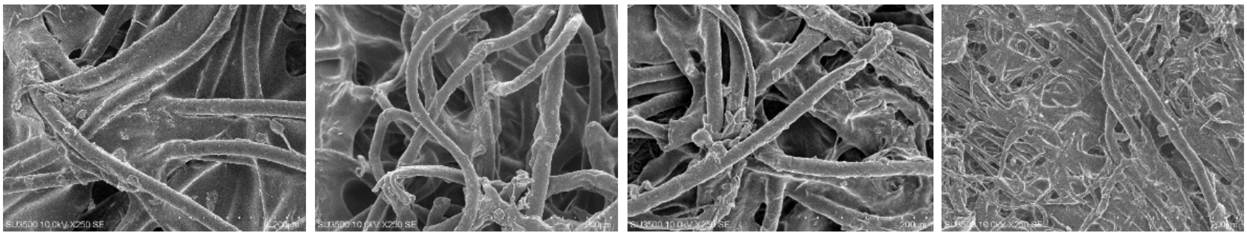

Fig. 2. Acoustic Material Morphology (Left to right: Sample 1, 2, 3, 4)

From the Fig. 2, we can see the surface of the panel which has many voids or pores. The porous nature of the material means it can reduce sound level because sound waves will enter and rub against the existing pores so that the amount of energy reflected is reduced (Çelikel & Babaarslan, 2018; González, 2019). Respectively, the average pore sizes in sample 1, 2, 3, and 4 are 109,48 μm, 69,31 μm, 53,66 μm, and 25,75 μm. These findings indicate that the more coconut fiber and the less non-woven polypropylene contained in the acoustic material, the smaller the pore size formed in the acoustic material. Previous research has revealed that materials with relatively larger pores can absorb sound better than relatively small pores. This is because the relatively large sized pores are easily connected effectively with adjacent pores, in which more sound waves can be distributed favorably (Chen et al., 2020). However, another research states that this concept only applies to sounds at a frequency up to 1250 Hz because sounds with higher frequencies have short wavelengths, so the pore size does not have a big influence (Amares et al., 2017).

Samples Mass Change

The Thermogravimetric Analysis test result shows changes in the mass of the acoustic material samples in the temperature range of 20°C to 560°C. The mass change graph is shown in Fig. 3.

The graph depicts mass changes in three different temperature ranges, that are <250°C, 250°C-400°C, and >400°C. In the temperature range <250 °C, the mass change of the four samples showed a relatively stable level. Meanwhile, in the temperature range of 250-400°C shows differences in the mass change of different samples. Sample 1 shows a mass change reaching 30,98% at a temperature of 400°C. Meanwhile, samples added with coconut fiber which are sample 2, 3, and 4, each had mass change of 24,23%, 22,12%, and 25,28%, respectively. In the temperature range above 400 °C, there was a continuous decrease in mass for the four samples, leaving only around 2,84% to 4,45% of the sample mass. Thus, sample 1 which does not contain coconut fiber shows better thermal stability, which can be explained by the composition of the inorganic material in the form of non-woven polypropylene which has unique properties in terms of physical, mechanical and thermal tolerance (Cao et al., 2018). This provides an indication that sample 1's sound absorption ability is less affected by temperature change of the environment compared to other samples.

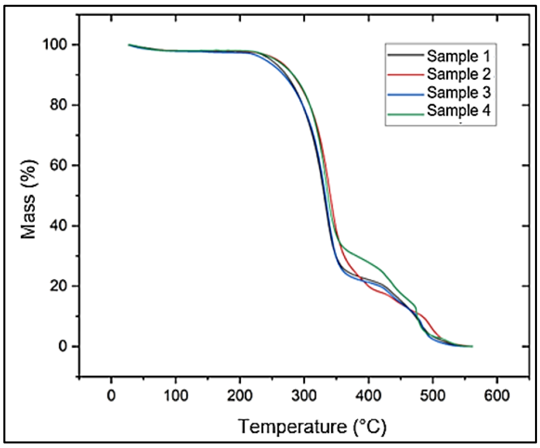

Fig. 3. Mass Change Percentage

Samples Density

The result of density test shows that the more coconut fiber used, the higher the density of the material. Density of each material can be seen in Table 2.

Table 2. Acoustic Material Density

Sample	Volume	Mass	Density
1	235,5 cm^3	90 gr	0,38 gr/cm^3
2		94 gr	0,4 gr/cm^3
3		97 gr	0,41 gr/cm^3
4		100 gr	0,42 gr/cm^3

This result is in line with the Scanning Electron Microscopy result which shows that the more coconut fiber contained in the composition, the smaller the pore size formed in the acoustic material. Previous research suggests that sound absorption efficiency is increased along with decreasing density in non-woven fiber (Santhanam et al., 2019). However, different result is shown in material made from coconut fiber which has a higher sound absorption coefficient as the density increased (Bhingare & Prakash, 2021). This contradictive result may be due to different characteristic between natural and non-natural materials because some materials are naturally porous and able to absorb the sound despite its high density (Febriyanti et al., 2024).

Samples Sound Absorption Coefficient

Sound absorption test result for each sample in six frequencies can be seen in Table 3 and Figure 3. According to ISO 11654, the minimum coefficient for a material to be categorized as a sound absorber is 0,15. Based on the results, all samples show a sound absorbing ability for sound with 500Hz and 2000Hz frequencies.

Table 3. Sound Absorption Coefficient of Acoustic Material

Sample	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1	0,137	0,108	0,234	0,102	0,165	0,090
2	0,065	0,088	0,193	0,019	0,159	0,070
3	0,053	0,077	0,215	0,087	0,236	0,082
4	0,031	0,046	0,201	0,060	0,151	0,078

However, from the graph seen in Figure 3, sound with 500Hz and 2000Hz frequencies have different samples with the highest sound absorption coefficient. Sample 1 with 100% non-woven polypropylene composition has the highest coefficient at 0,234 for 500Hz frequency. Meanwhile, sample 3 with 90% non-woven polypropylene and 10% coconut fiber has the best coefficient compared to other samples for 2000Hz frequency.

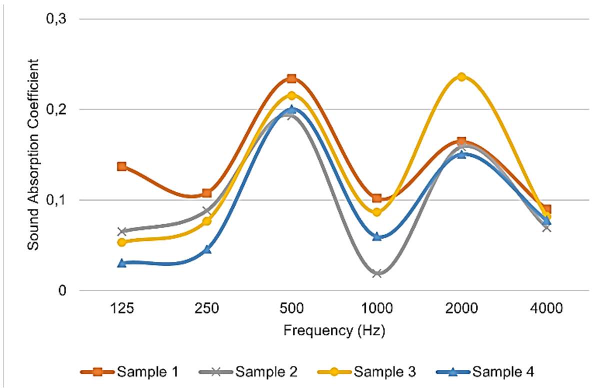

Fig. 4. Sound Absorption Coefficient Graph

In its application, sound absorber has the role in reduction of sound levels and control of reverberation (Cucharero et al., 2019). This can be implied that sample 1 is the best at reducing sound level at lower frequency, so it is suitable for installation in rooms with speech activities, whereas sample 3 is more appropriate to be used in rooms with musical activities because it is best at reducing sound level at higher frequency (Khonglah & Prasanna, 2016).

CONCLUSION

Based on research that had been conducted, acoustic materials made from disposable mask waste and coconut fiber exhibit sound absorption characteristics based on its morphology, mass change in different temperatures, density, and sound absorption coefficient. Acoustic material with 100% non-woven polypropylene displays the best sound absorber characteristics compared to other material with different compositions with the largest pore size, the best thermal tolerance, and the lowest density. It also has the highest sound absorption coefficient for 500Hz frequency sound. However, a better sound absorption coefficient in 2000Hz frequency sound is shown by acoustic material with composition of 90% non-woven polypropylene and 10% coconut fiber. The result implies that acoustic materials made from disposable mask waste and coconut fiber can be used for acoustic application.

ACKNOWLEDGEMENT

The author would like to express gratitude to Universitas Pendidikan Indonesia for the funding, support and assistance during this research as well as Direktorat Pembelajaran dan Kemahasiswaan (Belmawa) Kementerian Pendidikan dan Kebudayaan Republik Indonesia for funding this research.

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